Chapter 10. BENEFIT-COST COMPARISONS

This Regulatory Impact Analysis (RIA) provides cost, economic impact, and benefit estimates that are potentially useful for evaluating alternative illustrative visibility goals for the regional haze (RH) rule. Benefit-cost analysis provides a systematic framework for assessing and comparing such alternatives. According to economic theory, the efficient alternative maximizes net benefits to society (i.e., social benefits minus social costs). However, there are practical limitations for the comparison of benefits to costs in this analysis. This chapter also discusses the key limitations and uncertainties associated with the benefit and cost estimates. Nonetheless, if one is mindful of these limitations, the relative ordering and magnitude of the benefit-cost comparisons presented here can be useful information.

Results of the national analysis of estimated benefits and costs in the 2015 analysis year are presented for the two emission control cases detailed in Chapter 3. These cases, A and B, correspond to cases where additional fugitive dust controls are allowed as a control strategy and where fugitive dust controls are not allowed, respectively. For each case, costs, benefits, and net benefits are presented for the four illustrative visibility goals and the goal of baseline visibility, equivalent to setting the goal equal to visibility conditions at the baseline level of emissions. Note that the costs presented here do not include the monitoring and administrative costs in Chapter 7. In addition, an illustrative regional analysis is presented based on the results for Case A.

10.1 Summary of Cost Estimates: Case A

This section provides a summary of cost results for control-strategy Case A presented in chapter 6 of this RIA. Table 10-1 summarizes the total annual control cost estimates developed in this analysis for the year 2015. These costs reflect illustrative control scenarios applied to point, area, and mobile sources. The majority of the projected total national annual cost for these alternatives is due to control by transportation agencies of emissions from paved and unpaved roads, and control of emissions from utilities. However, as noted in Chapter 6, there is a great deal of uncertainty regarding fugitive dust emissions and their contribution to visibility impairment.

Table 10-1
Estimated Total Annual Cost of Regional Haze Illustrative Goals in 2015: Case A[a]

Illustrative Goal	Total Annual Costs (million 1990$)
Baseline visibility	$0
1.0 dv/15 years	$1,070
1.0 dv/10 years	$1,740
5% dv/10 years	$1,510
10% dv/10 years	$4,380

[a] For this chapter, all costs and benefits are rounded to the nearest 10 million. Thus, figures presented in this chapter may not exactly equal benefit and cost numbers presented in earlier chapters.

10.2 Summary of Benefits Estimates: Case A

Table 10-2 summarizes the total annual benefits for control-strategy Case A developed in this analysis for the year 2015 for the low-end and high-end sets of assumptions described in Chapter 9. Not all possible benefits or disbenefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2 in Chapter 9 of this RIA.

Table 10-2
Estimated Range of Annual Quantified Benefits
for Illustrative Regional Haze Visibility Goals in 2015: Case A[a,b]

Illustrative Goal	Annual Quantified Benefits (million 1990$) Low-End	Annual Quantified Benefits (million 1990$) High-End
Baseline visibility	$0	$0
1.0 dv/15 years	$1,350	$5,560
1.0 dv/10 years	$1,820	$7,110
5% dv/10 years	$1,610	$6,800
10% dv/10 years	$2,560	$18,740

[a] Not all possible benefits or disbenefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2 in Chapter 9 of this RIA.
[b] For this chapter, all costs and benefits are rounded to the nearest 10 million. Thus, figures presented in this chapter may not exactly equal benefit and cost numbers presented in earlier chapters.

10.3 Summary of National Net Benefits: Case A

Table 10-3 summarizes the total annual net benefits for emissions control Case A for the four illustrative RH visibility goals for the year 2015. There are several conclusions that can be drawn from Table 10-3.

- For the high-end assumption set, monetized net benefits are positive and substantial for all illustrative visibility goals.

- Although the 10% dv/10 years visibility goal has the largest associated benefits under both the high- and low-end assumption sets, the high cost of meeting this goal makes it the most undesirable option from an economic perspective based on the low-end benefits estimate. Based on the high-end benefits estimates, the 10% dv/10 years goal becomes the preferred goal. However, this depends largely on the increase in PM-related health benefits, rather than increases in visibility benefits (although visibility benefits are also greatest for the 10% dv/10 years goal). For the high-end set of assumptions, the 1.0 dv/15 years is the most undesirable option from an economic efficiency perspective.

- Using the high-end benefits estimates, net benefits are greatest at the most stringent illustrative goal evaluated, i.e., 10% dv/10 years. Using the low-end estimates of benefits, the 1.0 dv/15 years goal yields the highest net benefits. This demonstrates the sensitivity of the goal ordering to the set of assumptions about benefits estimation. At the high end, net benefits for the 10% dv/10 years option are approximately 2.7 times higher than for the next best option (1.0 dv/10 years). At the low end, net benefits for the 1.0 dv/15 years option are approximately 2.7 times higher than the next best option (5% dv/10 years).

- Benefit-cost ratios for the illustrative goals range from 0.6 to 1.3 for the low-end set of assumptions and from 4.1 to 5.2 for the high-end set of assumptions. It should be noted that while the 10% dv/10 years goal has the highest net benefits under the high-end assumption set, the 1.0 dv/15 years goal has the highest benefit-cost ratio under both the low-end and high-end assumption sets. So in terms of dollar benefits per dollar of cost, the 1.0 dv/15 years goal is the dominant goal under both the high and low set of assumptions. This suggests that in terms of robustness of goal ordering to increases in benefits, the 1.0 dv/15 years goal is the most stable.

Table 10-3
Estimated Plausible Range of Annual Quantified Net Benefits[a,b]
for Illustrative Regional Haze Visibility Goals 2015: Case A

Illustrative Goal	Annual Quantified Net Benefits (million 1990$) Low-End	Annual Quantified Net Benefits (million 1990$) High-End
Baseline visibility	$0	$0
1.0 dv/15 years	$280	$4,490
1.0 dv/10 years	$80	$5,370
5% dv/10 years	$100	$5,290
10% dv/10 years	($1,820)	$14,360

[a] Calculated as quantified benefits minus costs. Not all possible benefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2 in Chapter 9 of this RIA.
[b] For this chapter, all costs and benefits are rounded to the nearest 10 million. Thus, figures presented in this chapter may not exactly equal benefit and cost numbers presented in earlier chapters.

10.4 Summary of Cost Estimates: Case B

This section provides a summary of cost results for emissions control Case B presented in Chapter 7 of this RIA. Table 10-4 summarizes the total annual control cost estimates developed in this analysis for the year 2015. These costs reflect illustrative control scenarios applied to point, area, and mobile sources. A significant portion of the total national annual cost for these alternatives is due to control of utility sources that emit nitrogen oxides (NOx) and sulfur oxide ($SO_{2)}$.

Table 10-4
Estimated Total Annual Cost of Regional Haze Illustrative Goals in 2015: Case B[a]

Illustrative Goal	Total Annual Costs (million 1990$)
Baseline visibility	$0
1.0 dv/15 years	$750
1.0 dv/10 years	$1,430
5% dv/10 years	$1,240
10% dv/10 years	$3,610

[a] For this chapter, all costs and benefits are rounded to the nearest 10 million. Thus, figures presented in this chapter may not exactly equal benefit and cost numbers presented in earlier chapters.

10.5 Summary of Benefits Estimates: Case B

Table 10-5 summarizes the total annual benefits for control-strategy Case B developed in this analysis for the year 2015 for the low-end and high-end set of assumptions described in Chapter 9. Not all possible benefits or disbenefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2 in Chapter 9 of this RIA.

Table 10-5
Estimated Plausible Range of Annual Quantified Benefits for Illustrative Regional Haze Visibility Goals 2015: Case B[a,b]

Illustrative Goal	Annual Quantified Benefits (million 1990$) Low-End	Annual Quantified Benefits (million 1990$) High-End
Baseline visibility	$0	$0
1.0 dv/15 years	$810	$4,280
1.0 dv/10 years	$1,170	$9,730
5% dv/10 years	$1,140	$9,410
10% dv/10 years	$1,840	$19,350

[a] Not all possible benefits or disbenefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2 in Chapter 9 of this RIA.
[b] For this chapter, all costs and benefits are rounded to the nearest 10 million. Thus, figures presented in this chapter may not exactly equal benefit and cost numbers presented in earlier chapters.

10.6 Summary of National Net Benefits: Case B

Table 10-6 summarizes the total annual net benefits for control-strategy Case B for the four illustrative RH visibility goals for the year 2015. There are several conclusions that can be drawn from Table 10-6.

- For the high-end assumption set, monetized net benefits are positive and substantial for all illustrative visibility goals.

- Although the 10% dv/10 years visibility goal has the largest associated benefits, the high estimated cost of meeting this goal makes it the most undesirable option from an economic efficiency perspective based on the low-end benefits estimate. Based on the high-end benefits estimates, the 10% dv/10 year goal becomes the preferred goal. However, this depends largely on the increase in PM-related health benefits, rather than increases in visibility benefits. For the high-end estimates, the 1.0 dv/15 years is the most undesirable option from an economic efficiency perspective.

- Using the high-end benefits estimates, net benefits are greatest at the most stringent illustrative goal evaluated, i.e., 10% dv/10 years. Using the low-end estimates of benefits, the 1.0 dv/15 years goal yields the highest net benefits. This demonstrates the sensitivity of the goal ordering to the set of assumptions about benefits estimation. At the high end, net benefits for the 10% dv/10 years option are approximately 1.9 times higher than for the next best option (1.0 dv/10 years). At the low end, net benefits are positive only for the 1.0 dv/15 years option and $317 million higher than the next best option (5% dv/10 years).

- While net benefits are negative for the low-end set of assumptions for all but the 1.0 dv/15 years goal, it is important to remember that while all of the pollution control costs are included[1], many benefit categories could not be quantified. In addition, the low-end assumption set is designed to yield a very conservative measure of monetized benefits. Relaxing just one of the low-end assumptions, such as using willingness-to-pay as a measure of the value of an avoided case of chronic bronchitis instead of the cost-of-illness, leads to positive net benefits for all but the 10% dv/10 years goal.

- Benefit-cost ratios for the illustrative goals range from 0.5 to 1.1 for the low-end set of assumptions and from 5.4 to 7.6 for the high-end set of assumptions. It should be noted that while the 10% dv/10 years goal has the highest net benefits under the high-end

[1] Pollution control costs do include monitoring or administrative costs. Costs are only direct pollution control costs and do not measure social costs such as changes in consumer or producer surplus resulting from implementation of control strategies.

assumption set, the 5% dv/10 years goal has the highest benefit-cost ratio under the high-end assumption set. So in terms of dollar benefits per dollar of cost, the 1.0 dv/15 years goal is the dominant goal under the low set of assumptions and the 5% dv/10 years is the dominant goal under the high-end set of assumptions.

Table 10-6
Estimated Plausible Range of Annual Quantified Net Benefits[a,b]
for Illustrative Regional Haze Visibility Goals 2015: Case B

Illustrative Goal	Annual Quantified Net Benefits (million 1990$) Low-End	Annual Quantified Net Benefits (million 1990$) High-End
Baseline visibility	$0	$0
1.0 dv/15 years	$60	$3,530
1.0 dv/10 years	($260)	$8,300
5% dv/10 years	($100)	$8,170
10% dv/10 years	($1,770)	$15,740

[a] Calculated as quantified benefits minus costs. Not all possible benefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2 in Chapter 9 of this RIA.
[b] For this chapter, all costs and benefits are rounded to the nearest 10 million. Thus, figures presented in this chapter may not exactly equal benefit and cost numbers presented in earlier chapters.

10.7 Regional Net Benefit Analysis

Given the flexibility provided by this rule for state determination of visibility goals, a regional analysis of costs and benefits based on the six control cost regions identified in Chapter 6 of this RIA is presented below. This analysis is focused on determining whether selection of visibility goals on a regional basis provides a greater level of total net benefits compared to selection of a single national visibility goal. In addition, the analysis will examine the rank ordering of benefits and costs by region relative to the national rank ordering.

Table 10-7 presents the results of the regional goal selection analysis for emission control Case A. Several important assumptions unique to the regional analysis should be considered when interpreting this analysis. The first assumption is that visibility benefits accrue to the region in which the visibility change occurs, rather than to the region in which the population valuing the visibility change lives. This assumption implies that for a given region the "optimal" choice of a visibility goal should depend on the willingness to pay for visibility improvements of all populations, rather than just the populations in the region. The second assumption is that regions are broadly separable in air quality, i.e., changing the visibility goal for a region has no impacts on

benefits in other regions. This allows us to sum the benefits from different regions selecting different visibility goals without having to run new air quality analyses for each permutation of regional visibility goals. To simplify the analysis, we focus only on the air quality generated under emission control Case A in calculating benefits for each region and for the national comparison estimate. Regionality results are presented assuming both residential and recreational visibility benefits are included in the estimate of total visibility benefits. Results are presented for both the low-end and high-end sets of assumptions about PM-related health benefits. Specific assumptions are indicated in the table footnotes.

Table 10-7
Optimal Regional Visibility Goals and Associated Net Benefits: Case A[a]

Region	Low-end[c]		High-end[d]	
	Optimal Goal	**Net Benefits (million 1990$)**	**Optimal Goal**	**Net Benefits (million 1990$)**
West	1.0 dv/15 years	$49	10% dv/10 years	$2,140
Southeast	1.0 dv/10 years	$174	10% dv/10 years	$1,108
South Central[b]	1.0 dv/15 years	$420	10% dv/10 years	$1,036
Rocky Mountain	Baseline visibility	$0	10% dv/ 10 years	$1,152
Northwest	5% dv/10 years	$40	10% dv/10 years	$4,117
Midwest/ Northeast	1.0 dv/15 years	$19	10% dv/10 years	$4,725
Total 6 Control Cost Regions		**$702**		**$14,278**
United States	**1.0 dv/15 years**	**$250**	**10% dv/10 years**	**$14,278**
Efficiency Gain		**$451**		**$0**

[a] Not all possible benefits or disbenefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2 in Chapter 9 of this RIA. Optimal goal selected based on maximization of net benefits over all illustrative goals plus the baseline visibility goal.

[b] We did not model all possible efficient goals. Regions can choose an option outside of the modeled set to ensure positive net benefits.

[c] Low-end incorporates the following assumptions: 1) Residential visibility benefits excluded 2) WTP for visibility at non-NPS Class I areas is included in WTP for NPS Class I areas, 3) mortality is valued using the $2.2 million VSL based on the statistical life year approach, 4) chronic bronchitis is valued using a cost of illness value of $59,000 per case, and 5) PM health effects threshold equal to 15 $\mu g/m^3$. Due to rounding, the sum of the regional benefits may not exactly equal the national estimates.

[d] High-end incorporates the following assumptions 1) both residential and recreational visibility benefits included 2) WTP for visibility at non-NPS Class I areas is additive to WTP for NPS Class I areas, 3) mortality is valued using the $4.8 million VSL, 4) chronic bronchitis is valued using WTP of $260,000 per case, and 5) PM health effects threshold equal to anthropogenic background . Due to rounding, the sum of the regional benefits may not exactly equal the national estimates.

The next three sections provide a framework for analyzing the results of the regional analysis. The first of these sections discusses what economic theory tells us to expect from a regionally based approach relative to a nationally based approach. The second section examines how the rank ordering of the illustrative goals differs across regions. The third section discusses the optimally selected goals for each region and how the imposition of a threshold on PM-related health effects alters the results of the regionality analysis.

10.7.1 Expectations from Economic Theory

Class I areas are not homogeneous. For example, Class I areas in the west are generally greater in size than those found in the Midwest or northeast. More specific to this illustrative analysis, the Class I areas and the regions in which they are located may vary in terms of the nature of the visibility impairment problem. In particular, the ordering of the alternative illustrative visibility progress goals in terms of relative stringency is not the same for all regions of the country. This is true in terms of estimated benefits and costs (see table 6-11 in Chapter 6 and tables 9-15 through 9-17 in Chapter 9).

Failure to reflect the variability in costs and benefits in goal establishment and implementation plan development can result in inefficiencies. For example, while one of the illustrative goals may maximize positive net benefits on a national basis, that goal may not be the one that maximizes positive net benefits for the Class I areas in each of the regions. Furthermore with a uniform national goal, Class I areas in some regions may accrue zero net benefits, while Class I areas in other regions may have negative net benefits.

We assess the potential gains from recognizing regional differences by incorporating regional variability into this analysis. Specifically, Tables 10-4 and 10-5 identify the set of goals which results when each region chooses from among the four Aillustrative@ goals and the baseline visibility goal and selects the one that maximizes net benefits. Next, we compare the national net benefits from the optimal regional goals set with the net benefits from the optimal uniform national goal. The difference between the net benefits achieved from the optimal uniform national goal and net benefits from optimal regional goals is a measure of the efficiency gains available from regional flexibility.

As with the results from the national analysis, the calculated efficiency gain is conditional and merely illustrative. However, the analysis suggests that there may be efficiency gains from reflecting regional variability in the establishment and implementation of visibility progress goals.

10.7.2 Does the Ordering of Goals by Benefits and Costs Vary Across Regions?

The results presented in Table 6-11 in Chapter 6 and tables 9-15 through 9-17 in Chapter 9 indicate that when considered independently for costs and benefits, the ordering of the four illustrative goals does not vary much across regions for the low-end set of benefits assumptions. However, when costs and benefits are combined to form net benefits, the ordering is not preserved across regions. Table 10-4 demonstrates this by showing that the optimal, net-benefit maximizing goal differs across regions. Four of the five goals are selected by at least one region, suggesting that flexibility in goal establishment may lead to heterogeneity in goals selected across regions. The most stringent relative visibility goal was determined to be the most undesirable options for all regions (and thus was not selected by any region). Three regions selected the 1.0 dv/15 years goal while one region each selected the 1.0 dv/10 years, 5% dv/10 years and the "baseline visibility" goals. The selection of the baseline visibility goal by the Rocky Mountain region indicates that none of the four illustrative goals provided positive net benefits based on the low-end benefits assumptions. The efficiency gains due to the increased flexibility in goal selection equal approximately $451 million, approximately tripling the net benefits relative to a uniform goal for the nation.

Results are very different when the high-end set of assumptions is used to generate the benefits estimates. In this case, the ordering of benefits is not constant across regions, although the 10% dv/10 years goal always yields the highest benefits. The ordering of net benefits is also not constant across goals. However, compared to the low-end assumption set, the high-end estimates leads to no heterogeneity in optimal goals across regions. All six control cost regions select the 10%/10 years goal. As a result, the efficiency gain is from regional goal selection is zero. This suggests that the value of regional flexibility may be dependent on the relative differences between costs and benefits. In addition, it points out the sensitivity of this analysis to the assumptions about the PM health threshold, which tends to drive the large benefits in the high-end estimate.

10.7.3 Is There a Single Goal Which Maximizes Net Benefits Across All Regions?

The results presented in Table 10-4 indicate that there is no one dominant goal across regions, at least based on the low-end benefits estimates. The 1.0 dv/15 years goal is selected for half of the regions, while the other half choose either the 1.0 dv/10 years goal or baseline visibility. When the high-end benefits estimates are used in the net-benefits analysis, the 10% dv/10 years goal appears to be a dominant goal. However, it is important to note that the benefits associated with this goal are largely dominated by ancillary PM-health benefits, composed primarily of PM mortality related benefits. If visibility benefits are used as the primary decision factor in determining visibility progress goals, regions may exhibit greater heterogeneity in goal selection.

10.8 Findings and Qualifications

Cost-benefit analysis provides a valuable framework for organizing and evaluating information on the effects of environmental programs. When used properly, cost-benefit analysis helps illuminate important potential effects of alternative policies and helps set priorities for closing information gaps and reducing uncertainty. However, not all relevant costs and benefits can be captured in any analysis. Executive Order 12866 clearly indicates that unquantifiable or nonmonetizable categories of both costs and benefits should not be ignored. There are many important unquantified and unmonetized costs and benefits associated with the controls to reduce the emissions that lead to impaired visibility, including many health and welfare effects. Potential benefit categories that have not been quantified and monetized are listed in Chapter 9, Table 9-2 of this volume.

Several specific limitations deserve to be mentioned:

- The state of atmospheric modeling is not sufficiently advanced to provide a workable "one atmosphere" model capable of characterizing ground-level pollutant exposure for all pollutants of interest (e.g., ozone, particulate matter, carbon monoxide, nitrogen deposition, etc). Therefore, the Environmental Protection Agency (EPA) must employ several different pollutant models to characterize the effects of alternative policies on relevant pollutants. Also, not all atmospheric models have been widely validated against actual ambient data. In particular, since a broad-scale monitoring network does not yet exist for fine particulate matter ($PM_{2.5}$), atmospheric models designed to capture the effects of alternative policies on $PM_{2.5}$ are not fully validated. Additionally, significant shortcomings exist in the data that are available to perform these analyses. While containing identifiable shortcomings and uncertainties, EPA believes the models and assumptions used in the analysis are reasonable based on the available evidence.

- Another dimension adding to the uncertainty of this analysis is time. In the case of air pollution control, 15 years is a very long time over which to carry assumptions. Pollution control technology has advanced considerably in the last 10 years and can be expected to continue to advance in the future. Yet there is no clear way to model this advance for use in this analysis. In addition, there is no clear way to predict future meteorological conditions, or the growth in source-level emissions over time. Again, EPA believes that the assumptions to capture these elements are reasonable based on the available evidence.

- Qualitative and more detailed discussions of the above and other uncertainties and limitations are included in the analysis. Where information and data exist, quantitative characterizations of these uncertainties are included. However, data limitations prevent an overall quantitative estimate of the uncertainty associated with final estimates. Nevertheless, the reader should keep all of these uncertainties and limitations in mind

when reviewing and interpreting the results.